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RESEARCH VIEW

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Heavily Horned

Why are beetles the weaponry champs?

(Above) A rangifer dung beetle, about the size of a pencil eraser

University of Montana Professor Doug Emlen is passionate about animal weaponry. He's not alone in a state renowned for six-point bull elk and full-curl bighorn rams. But for Emlen, an evolutionary biologist, his selected choice of study is even more awesome. He focuses on the horns, forks, shovels and spatula weapons of beetles.

Here in the hometown of the Boone and Crockett Club, the official record keeper for trophy-sized game animals, Emlen might seem a bit cheeky in his assertion that horned beetles are the weaponry champions – until you take a closer look at the staggering array of the horns' shapes and sizes. Some dung beetle horns are so massive they make up 15 percent of the beetle's body weight. By comparison, a mature bull elk may weigh 700 pounds with a set of antlers as heavy as 40 pounds. Elk antlers would have to weigh 105 pounds to live up to beetle proportions.

"My research started with figuring out what beetle horns were for," Emlen says of his work of almost 20 years. "Today, I'm looking at the bigger question of the incredible diversity in their weapons."

Why would male beetles evolve so many kinds of weapons simply to fight rivals, protect territories and mate with females? Why would their weapons evolve faster than any other body part in a 40-million-year-old genus?

To untangle those mysteries, Emlen is applying "evo-devo," the nickname for the field of evolutionary developmental biology. Through his study of beetle horns, he tackles fundamental questions of science: How do you get variation in animal form? How do we get diversity?

During a Friday afternoon interview, Emlen sports a UM beetle lab T-shirt and a kid grin to match, embodying the quote from famed scientist E.O. Wilson: "Most children have a bug period, and I never grew out of mine."

Emlen's small office is jam-packed with beetle paraphernalia. A metal sculpture dung beetle rolls a ball with its hind feet. Mounted specimens of giant tropical beetles parade across a table. The ebony inward-sweeping horns of the Chalcosoma atlas are polished, sharp and formidable. Fossilized fish and trilobite-imprinted rocks add to the backdrop. Books on beetles and entomology crowd shelves. Papers and folders surround a large computer monitor, ideal for analyzing beetle horn growth at various life stages.

Within moments of my arrival, Emlen gently pulls out a Japanese rhinoceros beetle from a jar of leafy compost. The shiny black beetle with its imposing forked horn takes up his whole palm. I put out my hand — "Can I hold him?" It's time to prove my worth as a natural history writer. As the gigantic beetle crawls up my arm, I feel those six legs clinging like grappling hooks on my bare skin.

"I latch on to really bizarre things," Emlen tells me as I hand back the biggest beetle I've ever touched in my life. (The rhinoceros beetle holds the world record for strength relative to size. It can carry 850 times its body weight – the equivalent of a

Beetles – continued next page

Beetles – continued from front

person hefting 65 tons.)

Emlen's compelling subjects have generated a recent buzz in the national media. The New York Times ran a March 2009 Science section feature based on his recent paper in the Annual Review of Ecology, Evolution and Systematics called "The Evolution of Animal Weapons." In his article, Emlen reveals commonality within this medieval-looking arsenal. Pages of horn illustrations include the oversized claw of a fiddler crab, the pronged antlers of stag beetles, the whacky horns of rhinoceros beetles, a serrated blade on a fish's head, dinosaur horns and, of course, the antlers of the deer family.

So what is the common denominator? Emlen says that animal weapons evolve when males are able to defend a patch of territory with critical resources. A dung beetle guards a tunnel occupied by a female. A bull elk drives rivals away from his harem that he rounds up in a meadow. But what is not clear is why the weapons diverge so much in form.

"The potential for male competition to drive rapid divergence in weapon morphology remains one of the most exciting and understudied topics in sexual selection research today," he writes in the abstract. He explains that animal weaponry overall is studied far less than male ornamentation, such as peacock tails.

In Emlen's earlier dung beetle studies, he found that a big-horned male would guard a tunnel, while a small-horned male would dig a side tunnel to sneak in and mate with the prized female within. Both strategies lead to passing on genes. When you feed a beetle larva more, the horns grow larger in the pupa stage of metamorphosis. Feed him less, the resulting horns are smaller.

"It's not that hard to change these things once you have a feel for the developmental pathways," Emlen says of his nutrition investigations.

In February 2009, Emlen published an article in the esteemed journal Science about his co-discovery that a flashy neon-green dung beetle produces not two, but three kinds of males – large-horned, small-horned and a hornless male that resembles a female. This discovery of beetle male trimorphism opens up new questions for study. The hornless male indicates a third mechanism at work, as well as another strategy for success in passing on genes. Does a hornless male disguise himself as a female to find yet another way into the tunnel? For now, that's pure speculation.

UM biology Professor Doug Emlen and a Japanese rhinoceros beetle

Opposite Emlen's office is a spacious lab with microscopes and computers attended by graduate students who research subjects such as the correlation between a rhinoceros beetle's horn size and ability to fly well. Emlen opens a door into a walk-in closet lit with infrared bulbs to simulate the nocturnal conditions of active rhinoceros beetles – a mini-tropics, thick with the aroma of decaying leaves and fruit. We watch a pair of males joust horns over a rotting pear, while another guards a bamboo shoot.

A day earlier, an elementary school class visited the lab – a chance for kids to touch the tough carapaces and check out the very cool weapons. Emlen and the graduate student studying flight joked that the only time the rhinoceros beetle adults seem to fly willingly is in the presence of kids, not for the researcher who must coax them into flight with hair dryers that mimic a warm wind.

Emlen appears to take as much joy in sharing these beetle gladiators with kids as he does in the research itself. After all, in a few years these students may join him or others in labs as scientists continue to unravel evo-devo mysteries of species that have crawled, swum and flown on this planet for millions of years.

— By Deborah Richie Oberbillig

Weaponized Beetles

Onthophagus

Golofa

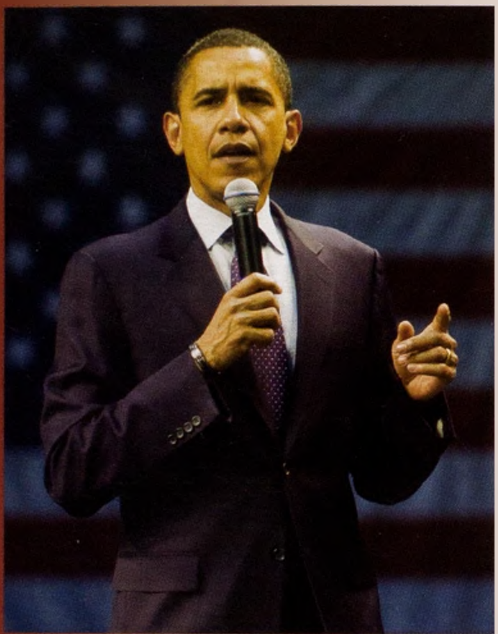
Enemapan

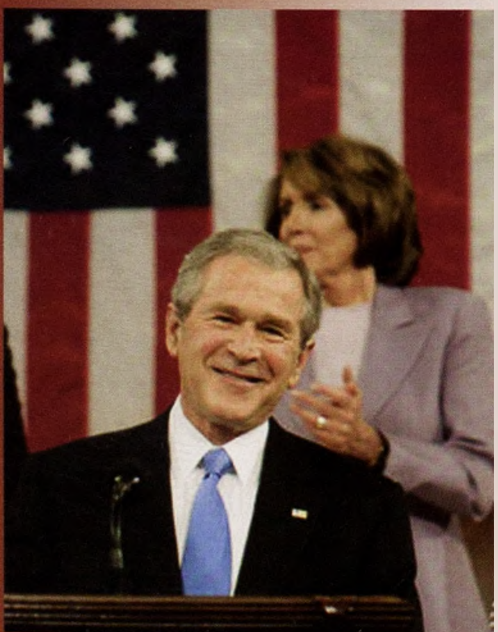
Dynastes

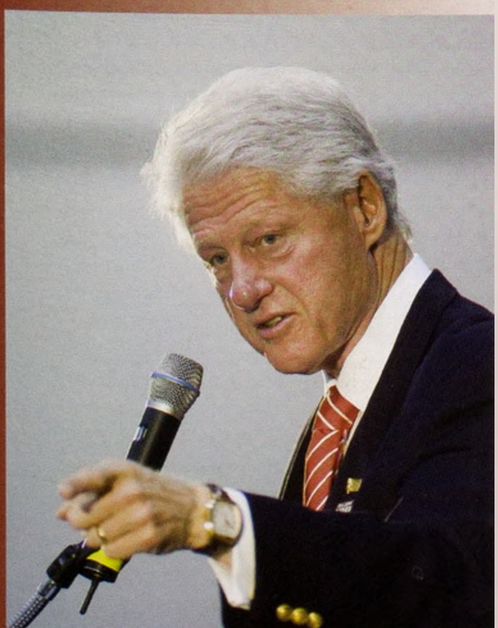
Phanaeus

Diversity and beetles go hand in hand. Beetles — some 350,000 different kinds — make up more than a quarter of all known species of living creatures on Earth. Recent findings suggest the earliest beetles date to 300 million years ago. That's 70 million years before dinosaurs made their mark. Apparently, says British evolutionary biologist and geneticist J.B.S. Haldane, the Creator had "an inordinate fondness for beetles."

Beetle images by D. Emlen, O. Helmy, B. Ewen-Campen and A. Johns







Complex Oration

Speeches offer clues to presidential success

In politics, words are everything — and more.

Lucian "Luke" Gideon Conway III, an assistant professor of psychology at UM, analyzes and codes political speech to detect patterns and determine whether simple or complex rhetoric is more effective.

He's also interested in defining what personality traits correspond with political speeches, such as cooperation and affiliation with various groups.

His findings have been featured in mainstream media outlets such as The Washington Post and the British Broadcasting Corp., as well as in academic publications such as the Journal of Personality and Social Psychology.

He's become so accustomed to coding language that his work seeps into his daily life.

"I code my mother's e-mails for complexity," the 37-year-old Conway says with a laugh as he explains his research in his cluttered office.

He and other coders in the UM lab use an "integrative complexity" construct to rank written or spoken statements on a scale of one to seven, as well as two other constructs of their own design to measure the component parts.

Conway says they measure how simply or complexly people think about a particular issue. It could be a straightforward: "Broccoli is terrible — I hate it." Or, it could be something that combines several thoughts and how they are interrelated: "Broccoli has a terrible texture and a nice flavor; but really, it's the way the flavor and texture combine in the palate that make the unique broccoli experience."

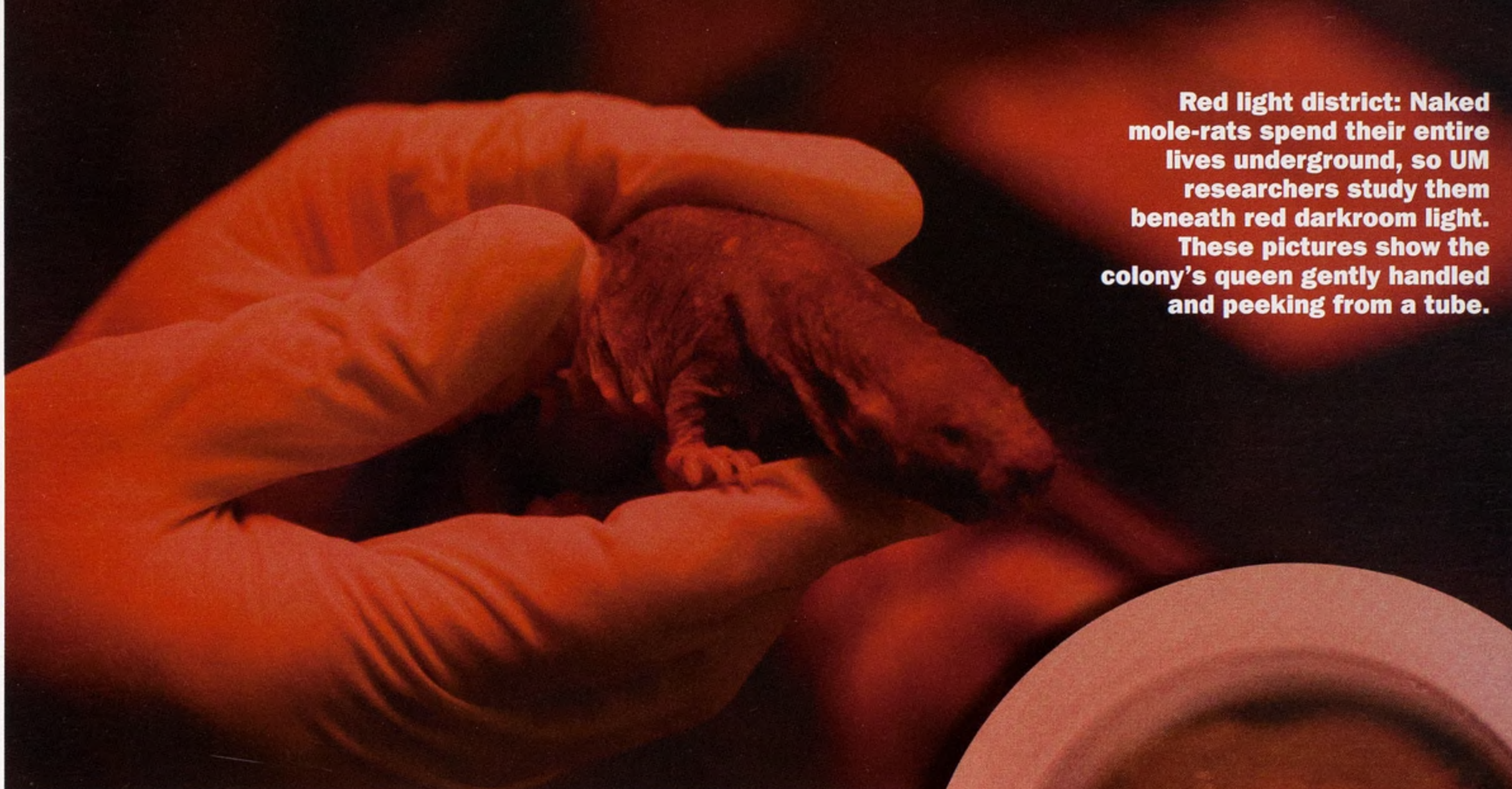
His recent work has homed in on State of the Union addresses of the past 40 presidents, starting with our nation's first president and concluding in 2004.

Typically, this annual speech gives a president a chance to offer a comprehensive, detailed platform that lays out his vision and sets his agenda for the year. All the major networks carry the speech in its entirety — a departure from most regular presidential coverage that is more sporadic and bounces from topic to topic.

Conway found an intriguing pattern in the State of the Union speeches he analyzed for "integrative complexity" in a paper published in

Speeches – continued last page

UM's Lucian Gideon Conway III



Red light district: Naked mole-rats spend their entire lives underground, so UM researchers study them beneath red darkroom light. These pictures show the colony's queen gently handled and peeking from a tube.

Tickled Pink!

What can nature's ugliest rodent teach us about the human brain?

For Christopher Comer, it's a good day when he can walk into his lab, loosen his tie and devote three solid hours to tickling naked mole-rats.

He's got his own collection of them – 35 rats in four colonies – which a colleague gathered in East Africa and Comer brought with him from his most recent professorship in Chicago. They're now burrowing, mating and carrying out their daily lives in their new laboratory home underneath UM.

At first glance, it appears evolution has not been tremendously kind to naked mole-rats. They are blind, bald and buck-toothed. They spend their entire lives underground. Farmers in their native East Africa revile them as pests. Perhaps the only animals appreciative of their existence are the snakes and birds that enjoy the wrinkled rats as snacks.

Comer, the new dean of UM's College of Arts and Sciences, has a poster in his office advertising an exhibit at Chicago's Brookfield Zoo that just about sums up the critters. "As if being a rat and a mole weren't bad enough," the poster reads, above a cartoon of a naked mole-rat looking particularly exposed.

"They're one of those creatures that people have strong reactions to," Comer admits. "Some people think they're ungodly ugly, and some people think they're really cute and fascinating and get really taken with them."

Comer makes no mystery of the group to which he belongs. After researching mole-rats for seven years, it's clear he's fond of his rodents. There's nothing but affection in his voice when he speaks of them.

"These guys are really unusual. They're eusocial, which is to say they have a social organization that's like some insects," Comer says. Every mole-rat colony has one queen, who is larger than the others and responsible for all reproduction. The other rats are divided into a caste system of workers, soldiers and nurses. Their carefully planned tunnel systems can be 2 miles long, housing colonies of up to 200 rats.

"I think it's a rare biologist who isn't a bit fascinated by the creatures they work on," he says. "It'd be hard to put in the time and the effort if you weren't."

Hence all the hours Comer devotes to studying his rats, in collaboration with Yoshi Baba, a research assistant professor in the Division of Biological Sciences who came from Chicago to UM with Comer. Both men know that mole-rats, like all mammals worth their mammary glands, reveal a lot about their true nature when tickled.

It's important to note that "naked mole-rats" is somewhat of a misnomer. While naked mole-rats lack fur, each has about 40 hairs, or vibrissae, on its body. Comer and his students have found that if a tiny filament of metal is attached to a particular vibrissa on the left side of a mole-rat's body and then vibrated (or tickled) in a magnetic field, they can predict how many degrees the rat will turn to the left. The farther back the hair is on the body, the farther the rat will turn. Tickle a hair on the right side and the animal will turn to the right.

Comer's research is part of a field called sensorimotor integration, which studies how sensory information in the brain is transmitted to the body as a message that determines a behavioral response.

Monkeys and humans exhibit sensorimotor integration when a light is flashed in their peripheral vision. Even if the light appears only for a few milliseconds, the subject's brain registers its location and directs the head to swivel until the eyes are aligned with it.

"The brain acquired the information of exactly where it was and sent a set of instructions to the neck muscles to move the head to exactly that target and stop there," Comer says. "It's something that seems trivial, but it's actually not, because it's a pre-programmed movement." Often, it happens so fast we don't even know we're doing it.

For any sensory stimulus an animal receives, thousands of cells fire off an electrical message on the input side of the brain. Then a translation circuit must rapidly process and decode the signals and send instructions to the muscles of the body to respond.

If this sounds a lot like the Six Million-Dollar Man, don't worry; a growing number of bioengineers think so, too. Comer says his field of research is attracting engineers eager to harness the power of biological circuits performing sophisticated tasks in order to design brain-operated prosthetic devices and biologically based robots. To do so, they need the help of Comer and other researchers to explain just how the circuitry works.

Scientists have already wired a monkey's brain waves and used them to move a robotic arm. When the monkey raised its limb, the robot followed suit. "That has obvious applications for what you might call 'intelligent prosthetic devices,'" Comer says. As a teaching model in his classroom, Comer and a colleague once connected the brain of a cockroach to a microchip in a robot. The robot moved to the left and right according to which of the insect's antennae was tickled.

Researchers Yoshi Baba and Christopher Comer with part of UM's new mole-rat colony.

When engineers perfect a way to digitize the detailed instructions the brain sends the body, they could, in theory, construct an artificial limb or wheelchair that would move as if it were an extension of the human form.

As profound as the applications of his findings may be, Comer doesn't focus his research entirely on the practical windfalls of understanding a mole-rat's brain. He also studies the rodents for their sake alone.

"Curiosity-driven experiments are good for us. I believe that passionately," he says. "Penicillin wasn't discovered because a task force said, 'Let's develop penicillin.' Somebody was doing a basic experiment on microbes and noticed something interesting."

Comer says this curiosity is a hallmark of American science in general and the National Science Foundation in particular. He directed the Behavioral Neuroscience Program at the foundation from 1993 to 1995 and has received a variety of NSF grants for his research projects.

"When you take bright people, put them in a laboratory and let them figure out how nature works, good things come from that," he says.

That's why Comer tries to make it to the lab every Wednesday morning, despite the other obligations inherent in overseeing the 23 departments and programs, 380 faculty, 60 staff and 7,000 students that make up the University's College of Arts and Sciences.

With a desk piled high in paperwork and every hour of his weekly planner filled with the duties of a dean, it's a relief for Comer when he can devote time to his rats, even if it means working into the night or on weekends.

"The nice thing about research is that you can say, 'For the next three hours, I'm going to focus on this one issue,'" he says.

For now, that issue is tickling naked mole-rats. And Comer's as happy as can be.

— **By Jacob Baynham**

A worker mole-rat races down a tube connecting the chambers of its UM home.

(Top) A Calliope hummingbird buzzes its wings at UM's Flight Laboratory. (Right) An image produced by particle image velocimetry reveals the speed and direction of forces moving around a flying hummingbird.

Fancy Flying

Research solves bird-flight mysteries

The mind wanders on long bike rides. Bret Tobalske found his own roaming as he pedaled to work in 1989, while pursuing his UM master's degree at Coram Experimental Forest near Hungry Horse. As the trees rolled past, he watched woodpeckers and their unusual heavy-flying style. It consisted of flapping bursts followed by short periods where the birds tucked their wings and coasted through the air – much like an Olympic ski jumper straining for that extra inch.

Why do they do that? Tobalske thought. Are they resting mid-flight?

Seemingly simple questions and a wandering mind can take a person a long way. He started studying this wing-tucking behavior used by many flying birds – called bounding – which led to other questions regarding the mechanics of bird flight. It also led him to earn a doctorate at UM, a Fulbright fellowship in France, postdoctoral work at Harvard and faculty positions at Allegheny College and the University of Portland.

Now he's the new director of UM's cutting-edge and recently renovated Flight Laboratory and Field Research Station at Fort Missoula. He took the reins from renowned bird researcher Ken Dial, who wanted more time to concentrate on writing and research. Dial was one of Tobalske's mentors during his graduate student days at UM.

"His research program is just on fire," Dial says of Tobalske. "He's more productive than I will ever be, and we are lucky to have him. I hope that together we can become an awesome force internationally regarding bird flight."

Tobalske says bounding is an excellent strategy for small, fast birds because air drag goes up exponentially with increasing flight speed. Occasionally closing their wings gets them out of the airstream and reduces drag. It also gives birds a brief rest, which is important because flying is one of the most energy-intensive ways for an animal to move. Tobalske also has learned that birds actually produce lift with only their bodies and tails.

"It's called body lift, and it's a contribution of just the cigar shape of the body and the tail itself," he says. "So during their bounding leap, they can support about 15 to 20 percent of their body weight with just their shape."

Studying the relationship between form and function in birds and why they choose to fly at different speeds has been an overarching theme of Tobalske's work for nearly two decades. In an early breakthrough while studying birds using wind tunnels and other techniques, he found the animals aren't constrained to use their muscles in a fixed way when they fly, which cut against the grain of scientific thought at the time.

Tobalske also started thinking about how air is essentially a non-dense fluid, and that the power generated internally by birds as they flap their wings should have interesting effects on the air "fluid flow."

"As the animal pushes down on the air, the air pushes back on the animal and it stays in the air," he says. "You have equal but opposite forces, as described by Newton's Third Law."

In order to visualize these invisible aerodynamic forces, Tobalske became an early expert at using particle image velocimetry on flying birds. During this process, a chamber is filled with a fine mist of olive oil. It looks like a smoky bar but smells like a pizzeria. A laser is then shot against a bird as it flies. Computers and high-speed cameras that shoot 1,000 frames per second then record the mini-tornadoes of oil particles formed by the bird's wings and body.

The process produces digital images in which tiny swirls of arrows reveal the speed and direction of forces moving around the bird. The pictures are so interesting that in 2004 Tobalske was approached by artist Fernanda D'Agostino, a UM alum who now lives in Portland, to colorize his scientific work. The results have been exhibited in China and at technology conferences in France and Spain.

"It's been a real integration of art and science and something I never imagined I would get into," Tobalske says.

He brought his $150,000 PIV system with him when he became director of UM's Flight Laboratory last August. He believes it's the first time this technology has been available on campus.

Tobalske has worked with a wide variety of birds over the years, and not all of them are willing to fly on demand inside a mist-filled box while being shot by lasers. Tobalske admits to many fruitless hours trying to get stubborn pigeons to fly in such a situation. So he and his partners turned to one of nature's supreme fliers — the hummingbird.

"Of the 9,000 species of birds, hummingbirds are the best," he says. "Their default setting is flying. Other birds want to sit and perch, but we once had this female hummingbird that set the record by flying for 90 minutes straight — and that's at 40 wing beats per second."

Though hummingbirds generally weigh only as much as three paperclips, they can be highly aggressive and territorial with one another, especially the males. Tobalske has research video of a male viciously dive bombing one of its fellows and chasing it off. He generally studies Rufous hummingbirds, which are found in Montana. He says the birds migrate and can zip around at 25 mph.

Hummingbirds are interesting to Tobalske because they can hover and fly much like insects. They use a figure-eight sweeping motion when they fly, much like a human treads water. For years scientists assumed that the upstroke and downstroke of hummingbird wings support the birds equally as they flew, as they do with dragonflies and bees.

Bret Tobalske, director of UM's Flight Lab and Field Research Station (http://fieldstation.dbs.umt.edu)

"But what we observed is that while hummingbirds converge on the bee style of flight, they retain a little bit of the bird component, where the upstroke does less than the downstroke does," Tobalske says. "With most birds, there is evidence that the upstroke is inactive — that it is just a recovery stroke that sheds a bit of drag. But somewhere along the way, hummingbirds acquired the ability to support a little bit of their weight with the upstroke."

In another major observation, Tobalske learned that hummingbirds flip their wings over at the end of each wing stroke, using a technique called pronating and supinating. So hummingbird lift comes from both sweeping their wings and then spinning them.

"This is the first time this has ever been shown in a live animal," he says. "Insects do flip their wings similar to hummingbirds. But insects, lacking an internal skeleton, can't use the muscles and pectoral girdle and wings to actively alter the twist and curvature of the wing like a hummingbird does."

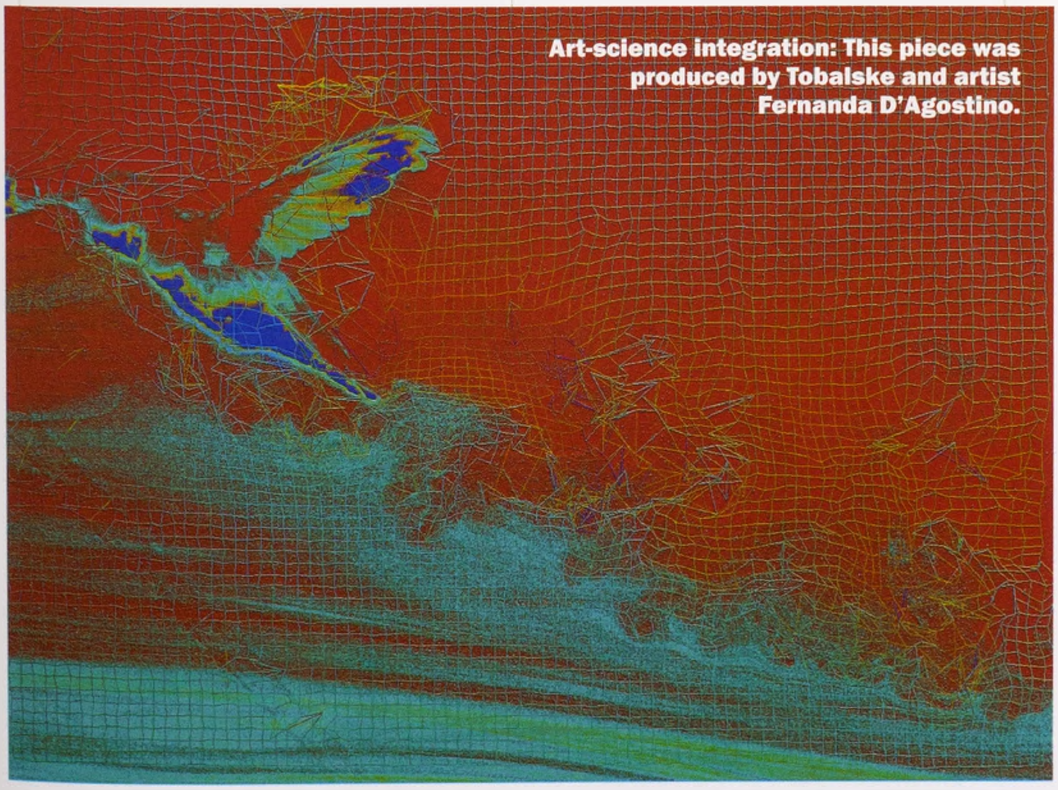
Tobalske's partners in this research are Doug Warrick of Oregon State University and Don Powers of George Fox University. During the past three years, they have used a movable feeding apparatus filled with sugar water to turn hummingbirds around 180 degrees as they fly while their wake is illuminated by lasers in the misty PIV chamber.

"We can move the birds back and forth, side to side, whatever we want," Tobalske says. "So our next step will be to actually study maneuvering."

Part of the reason he studies bird flight is from pure fascination, but he hopes understanding how feathered creatures move about and migrate will ultimately help wildlife managers with their ecology and conservation efforts.

Waving goodbye at the end of his interview, Tobalske says, "We humans are so visual that for us it doesn't exist until you see it. But when you wave to somebody, you have created a whole invisible vortex trail in the air, just as a bird does. It's just that you aren't using it to support your weight."

— By Cary Shimek



Art-science integration: This piece was produced by Tobalske and artist Fernanda D'Agostino.

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the journal Political Psychology. And the pattern held true over generations, regardless of whether the researchers were analyzing George Washington or George W. Bush.

Conway's research with co-author Felix Thoemmes, a graduate student at Arizona State University, revealed that the speeches displayed higher levels of complexity in a president's first three State of the Union addresses. But the complexity of speech plummeted during the fourth year as the president prepared his next run for office.

Why? It may be that presidents simplify their messages to win elections. At the beginning of their terms in office, they increase the complexity of their speeches as they sketch out the costs, dissenting points of view and any possible consequences of their policies. When their terms are up, they offer simple solutions as they begin their re-election campaigns.

For example, Bill Clinton's rallying cry, "It's the economy, stupid," helped drum up support prior to his successful 1992 campaign against George H.W. Bush.

Conway says another possible reason for the simpler message in the fourth year is cognitive fatigue.

"Presidents may literally wear down from the constant focus on them and work matters," he says.

Indeed, it is possible that successful presidents are those who avoid this fatigue longer. For example, Conway's research revealed that presidents who successfully won re-election for a second term were "really good at maintaining complexity for a longer period of time and, quite possibly, were more successful at their jobs as a result. Maybe the reason they got re-elected was because the populace recognized they did a better job."

But incumbent presidents who were not re-elected showed a drop in complexity that occurred very soon in their presidency, suggesting they "simply ran out of intellectual steam too early," Conway says.

But Conway doesn't want people to assume that complexity always is good and simplicity always is bad. Actually, a

lot of research indicates that complexity often is really bad. English Prime Minister Neville Chamberlain, for example, was complex in dealing with Hitler (bad), and the compromise of 1850 was driven by complex people from the North willing to compromise on slavery (bad).

"It was simple, straightforward people who stopped the Holocaust, like Churchill, and slavery, like the Northern Abolitionists," Conway says.

One potential criticism levied at this work is that it could be the State of the Union speeches are not a good gauge of presidential thought, especially given the increased role of speechwriters since Calvin Coolidge created the first speech-writing staff in 1925. But Conway says he doesn't put too much credence in this line of thinking because presidents are so deeply involved in their State of the Union speeches.

A Louisiana native who was raised in Texas, Conway received a bachelor's degree in 1994 from Baylor University in Waco, Texas. He earned a master's and doctorate in social psychology from the University of British Columbia in 1998 and 2001, respectively.

Conway now is trying to answer the question of why there is a drop in the complexity of presidents' speeches during their fourth year in office. More precisely, he wants to know why presidents with more simple views in their fourth State of the Union addresses are more likely to be re-elected.

To find possible answers, Conway is analyzing the 2004 Democratic presidential primary debates. His preliminary findings suggest that presidential candidates who gave complex arguments were less popular in public opinion polls than were those candidates who gave simpler explanations.

"We are investigating this because maybe simple rhetoric is more effective in elections," Conway says.

In Conway's initial analysis of 11 Democratic primary debates, he discovered the winners had a significant drop in the complexity of their arguments during the course of the debates.

"John Kerry and John Edwards started with high complexity and then dropped, while the losers had flat lines," Conway says.

His ongoing research also is looking at the 2008 presidential election.

Campaign rhetoric and debate between Barack Obama and John McCain was parsed into about 60 to 70 paragraphs and roughly split between domestic and foreign issues. For each paragraph, any identifiers were removed and the paragraph was scored for integrative complexity. These paragraphs then were given to college participants, who were asked various questions about how the paragraph would affect their vote.

"What we found is complexity worked better for McCain and simplicity worked better for Obama, and this was particularly true for foreign-policy issues," Conway says. "We speculate there is a compensatory action. There was a perception of McCain as a bit of a simple-minded hawk, so his complex rhetoric may have compensated for the stereotype."

So, given Conway's research, is complex or simple speech more effective?

"There are about 60 ways to answer that question," Conway says. "Interestingly, there is a slight correlation between complexity in rhetoric and historians' ratings of presidential greatness. Yet, in some ways, it's clear that in some specific campaign contexts simplicity can be very effective nonetheless."

— By Pamela J. Podger

Research View is published twice a year by the offices of the Vice President for Research and Development and University Relations at The University of Montana. Send questions, comments or suggestions to Cary Shimek, managing editor, 330 Brantly Hall, Missoula, MT 59812 (406-243-5914; cary.shimek@umontana.edu). Contributing editors are Jacob Baynham, Brianne Burrowes, Brenda Day, Rita Munzenrider, Jennifer Sauer, Patia Stephens and Ashley Zuelke. Todd Goodrich is the primary photographer. For more information, call Judy Fredenberg in the research and development office at 406-243-6670. The newsletter is online at http://www.umt.edu/urelations/rview.

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